PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference P20812	**FOR FURTHER ACTION**	See Form PCT/IPEA/416
International application No. PCT/AU2004/001687	International filing date *(day/month/year)* 1 December 2004	Priority date *(day/month/year)* 5 December 2003
International Patent Classification (IPC) or national classification and IPC Int. Cl.[7] G01B 7/16, G01L 1/18, 9/06, H01L 29/84		
Applicant THE COMMONWEALTH OF AUSTRALIA et all		

1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 3 sheets, including this cover sheet.
3. This report is also accompanied by ANNEXES, comprising:
   a. [X] *(sent to the applicant and to the International Bureau)* a total of 9 sheets, as follows:
      - [X] sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications authorized by this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions).
      - [ ] sheets which supersede earlier sheets, but which this Authority considers contain an amendment that goes beyond the disclosure in the international application as filed, as indicated in item 4 of Box No. I and the Supplemental Box.

   b. [ ] *(sent to the International Bureau only)* a total of (indicate type and number of electronic carrier(s)) , containing a sequence listing and/or table related thereto, in computer readable form only, as indicated in the Supplemental Box Relating to Sequence Listing (see Section 802 of the Administrative Instructions).
4. This report contains indications relating to the following items:
   - [X] Box No. I Basis of the report
   - [ ] Box No. II Priority
   - [ ] Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - [ ] Box No. IV Lack of unity of invention
   - [X] Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - [ ] Box No. VI Certain documents cited
   - [ ] Box No. VII Certain defects in the international application
   - [ ] Box No. VIII Certain observations on the international application

Date of submission of the demand 5 July 2005	Date of completion of the report 4 November 2005 8 NOV 2005
Name and mailing address of the IPEA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized Officer **EVA DE KOOL** Telephone No. (02) 6283 2477

ENTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.
PCT/AU2004/001687

ox No. I Basis of the report

With regard to the **language**, this report is based on the international application in the language in which it was filed, unless otherwise indicated under this item.

☐ This report is based on translations from the original language into the following language , which is the language of a translation furnished for the purposes of:

☐ international search (under Rules 12.3 and 23.1 (b))

☐ publication of the international application (under Rule 12.4)

☐ international preliminary examination (under Rules 55.2 and/or 55.3)

With regard to the **elements** of the international application, this report is based on (*replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report*):

☐ the international application as originally filed/furnished

☒ the description:

pages **6-18** as originally filed/furnished
pages* **1-5** received by this Authority on **5 July 2005** with the letter of **5 July 2005**
pages* received by this Authority on with the letter of

☒ the claims:

page **20** as originally filed/furnished
pages* as amended (together with any statement) under Article 19
pages* **19, 21-23** received by this Authority on **5 July 2005** with the letter of **5 July 2005**
pages* received by this Authority on with the letter of

☒ the drawings:

pages **1/4-4/4** as originally filed/furnished
pages* received by this Authority on with the letter of
pages* received by this Authority on with the letter of

☐ a sequence listing and/or any related table(s) - see Supplemental Box Relating to Sequence Listing.

3. ☐ The amendments have resulted in the cancellation of:

☐ the description, pages
☐ the claims, Nos.
☐ the drawings, sheets/figs
☐ the sequence listing (*specify*):
☐ any table(s) related to the sequence listing (*specify*):

4. ☐ This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since they have been considered to go beyond the ~~disclosure~~ as filed, as indicated in the Supplemental Box (Rule 70.2(c)).

☐ the description, pages
☐ the claims, Nos.
☐ the drawings, sheets/figs
☐ the sequence listing (*specify*):
☐ any table(s) related to the sequence listing (*specify*):

* *If item 4 applies, some or all of those sheets may be marked "superseded."*

ox No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

Statement

Novelty (N)	Claims	1-28	YES
	Claims		NO
Inventive step (IS)	Claims	1-28	YES
	Claims		NO
Industrial applicability (IA)	Claims	1-28	YES
	Claims		NO

Citations and explanations (Rule 70.7)

The following documents identified in the International Search Report have been considered for the purposes of this report:

D1) JP 03-037534 A (English Abstract)

D2) CH 517300 A

D3) GB 2174500 A

D4) GB 1344758 A

D5) US 5092177 A

D6) US 4166269 A

D7) US 4445385 A

D8) EP 454901 B1

Novelty (N) and Inventive Step (I.S.)

Claims 1-28: None of the cited documents (when considered alone or in combination) discloses or suggests coupling two load points along an indirect path. The prior art documents D1-D8 appear to teach coupling the load points along direct path(s) which exposes the sensors to both tensile and compressive forces, but does not result in the mechanical configuration as currently claimed, nor in its benefits. Consequently, it is considered that the invention as currently claimed in Claims 1-28 is both novel and inventive over the prior art documents.

Industrial Applicability (I.A.)

The invention as defined in Claims 1-28 is clearly industrially applicable in the field of strain sensors.

STRAIN GAUGE

FIELD OF THE INVENTION

The present invention relates to a strain gauge for measuring strain, of particular but by no means exclusive application in measuring strain in cramped environments.

BACKGROUND OF THE INVENTION

One existing type of strain gauge is the electrical resistance foil strain gauge. For uniaxial strain these typically require bridge completion and precision conditioning equipment. Further, electrical resistance foil strain gauges generally use higher power levels than is desirable and their use involves careful work by personnel owing to their low output signal levels.

Another broad type of gauge is the "clip" gauge, which incorporate a full bridge. However, clip gauges generally do not have a low profile, and are unsuitable for permanent installation. Further, they also consume considerable power and are relatively expensive.

Columbia Research Laboratories, Inc. produces a full bridge product using metallic gauges, but this does not have as high a sensitivity as is desirable in many applications.

Thus, existing strain gauges have relatively high power requirements, generally require bridge completion, and have low output signal levels.

SUMMARY OF THE INVENTION

The present invention provides, therefore, a strain gauge, a strain gauge, comprising:

a silicon strain sensing element for sensing strain and having first and second load points;

wherein said strain sensing element includes a

portion that couples said first and second load points along an indirect path, and has a pair of piezo-resistors located between said load points such that, when said strain sensing element is subjected to tension or compression at said load points, said portion respectively extends or bends subjecting a first of said pair of piezo-resistors to compression and a second of said pair of piezo-resistors to tension thereby inducing a change in relative resistance of said pair of piezo-resistors.

Preferably said strain sensing element comprises a curved silicon member (preferably a ring and more preferably a circular ring or annulus).

Those skilled in the art will understand that structures other than circular members can be used to generate compressive and tensile regions in silicon suitable for measuring using piezo-resistors. For example, alternatives include ellipses, ovals, one or more curves with one or more straight portions, and angular members (such as a "V" shape or a zig-zag member).

In one particular embodiment, the strain sensing element comprises a silicon ring or annulus.

The strain sensing element may include two or more load points and respective sets of piezo-resistors between each respective pair of load points. For example, the strain sensing element may comprise a ring with two load points and two pairs of piezo-resistors.

Preferably the strain sensing element comprises a silicon ring or annulus with a plurality of load points spaced substantially equidistantly around the perimeter of said ring or annulus.

The strain gauge may include a plurality of strain sensing

elements (such as silicon rings or annuli). Preferably each of said strain sensing elements include at least one load point coupled to a load point of another of said strain sensing elements.

In one embodiment, the strain gauge includes a plurality of strain sensing elements (such as silicon rings or annuli) arranged linearly, in a ring or other desired geometry each having a load point coupled to or common with a load point of any adjacent one or more of said strain sensing elements.

Preferably said gauge includes a detector responsive to changes in the relative resistance of said pair of piezo-resistors. Preferably said strain sensing element is provided with two pairs of piezo-resistors, arranged so as to constitute a Wheatstone Bridge.

In one particular embodiment, the strain sensing element is provided with a plurality of pairs of piezo-resistors, arranged so as to constitute a Wheatstone Bridge, and the gauge includes a current or potential sensitive device (such as an microammeter or differential amplifier) arranged to respond to changes in the relative resistance of said piezo-resistors.

In one particular embodiment, the strain gauge further includes an external structure, a plurality of connection points and a plurality of compliant tethers, wherein the connection points comprise or are mechanically coupled to the load points, and the tethers are arranged to tether the connection points to the external structure with each of the connection points coupled to the external structure by at least one of the tethers to locate the strain sensing element within the external structure.

The tethers may be sufficiently compliant so that a load

required to bend the tethers is small compared with a load required to distort the strain sensing element.

The external structure preferably comprises a silicon frame.

The connections points may comprise or be coincident with the load points.

In one embodiment, the tethers provide a platform for or constitute an electrical connection between the external structure and the strain sensing element. The tethers may comprise silicon.

Preferably the piezo-resistors are fabricated in pairs so that under compressive load one is in compression and one is in tension and under extensive load the one that was in compression is under tension and the one under tension is under compression.

Preferably piezo-resistors are arranged electronically to reduce changes in resistance due to thermal effects.

Preferably the other piezo-resistors are used in temperature correction for the piezo-resistors of the strain sensing element.

The strain gauge may comprise means to apply a bias voltage between the strain sensitive piezo-resistors of the compliant member and the substrate or doped well that they are in order to control response of the strain sensitive piezo-resistors.

The strain gauge may be fabricated with conductive tracks to the connection points so that material may be electro-deposited at the connection points to provide a raised point for bonding to an external structure for the

purposes of monitoring the strain in the external structure.

The strain gauge may include at least one electrical circuit fabricated on a wafer on which the strain gauge is manufactured to control processing of the wafer.

The at least one electrical circuit may control processing of electro-deposition.

BRIEF DESCRIPTION OF THE DRAWINGS

In order that the invention may be more clearly ascertained, embodiments will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a schematic view of a uniaxial strain gauge according to a first embodiment of the present invention;

Figure 2 is a schematic view of the strain sensing element of the strain gauge of figure 1;

Figure 3 is a schematic circuit diagram of a strain gauge measurement circuit for use with the strain gauge of figure 1;

Figure 4 is a plot of change in resistance $\Delta R\,(\Omega)$ as a function of microstrain for a strain gauge constructed according to the embodiment of figures 1 and 2;

Figure 5 is a schematic view of a biaxial strain gauge according to a second embodiment of the present invention;

Figure 6A is a photograph of an elongate strain gauge according to a third embodiment of the present invention; and

Figure 6B is a detail of the strain gauge of figure 6A.

CLAIMS:

1. A strain gauge, comprising:

a silicon strain sensing element for sensing strain and having first and second load points;

wherein said strain sensing element includes a portion that couples said first and second load points along an indirect path, and has a pair of piezo-resistors located between said load points such that, when said strain sensing element is subjected to tension or compression at said load points, said portion respectively extends or bends subjecting a first of said pair of piezo-resistors to compression and a second of said pair of piezo-resistors to tension thereby inducing a change in relative resistance of said pair of piezo-resistors.

2. A strain gauge as claimed in claim 1, wherein said strain sensing element comprises a curved silicon member.

3. A strain gauge as claimed in claim 2, wherein said curved silicon member comprises a circular ring or annulus.

4. A strain gauge as claimed in claim 1, wherein the strain sensing element has a shape selected from the group of an ellipse, an oval, one or more curves with one or more straight portions, a "V" shape and a zig-zag member.

5. A strain gauge as claimed in claim 1, wherein the strain sensing element comprises two or more load points and respective sets of piezo-resistors between each respective pair of load points.

6. A strain gauge as claimed in claim 5, wherein the strain sensing element may comprise a ring with two load points and two pairs of piezo-resistors.

15. A strain gauge as claimed in claim 1, wherein said strain sensing elements are connected to the load points by silicon tethers.

16. A strain gauge as claimed in claim 1, further including an external structure, a plurality of connection points and a plurality of compliant tethers, wherein said connection points comprise or are mechanically coupled to said load points, and said tethers are arranged to tether said connection points to said external structure with each of said connection points coupled to said external structure by at least one of said tethers to locate said strain sensing element within said external structure.

17. A strain gauge as claimed in claim 16, wherein said tethers are sufficiently compliant so that a load required to bend said tethers is small compared with a load required to distort said strain sensing element.

18. A strain gauge as claimed in claim 16, wherein said external structure comprises a silicon frame.

19. A strain gauge as claimed in claim 16, wherein said connections points comprise or are coincident with said load points.

20. A strain gauge as claimed in claim 16, wherein said tethers provide a platform for or constitute an electrical connection between said external structure and said strain sensing element.

21. A strain gauge as claimed in claim 16, wherein said tethers comprise silicon.

22. A strain gauge as claimed in claim 16, wherein said external structure includes other piezo-resistors fabricated on parts of said external structure so that said external structure can be used as a temperature sensor.

23. A strain gauge as claimed in claim 22, wherein said other piezo-resistors are used in temperature correction for the piezo-resistors of said strain sensing element.

24. A strain gauge as claimed in claim 23, comprising means to apply a bias voltage between said strain sensitive piezo-resistors of said strain sensing element and said external structure or a doped well in order to control response of said strain sensitive piezo-resistors.

25. A strain gauge as claimed in claim 24, including conductive tracks to said connection points so that material may be electro-deposited at said connection points to provide additional functionality at said connection points.

26. A strain gauge as claimed in claim 25, including material electro-deposited at at least one of said connection points to form a raised point at said respective connection point for bonding to an external structure for the purposes of monitoring strain in said external structure.

27. A strain gauge as claimed in claim 24, further comprising at least one electrical circuit fabricated on a wafer on which the strain gauge is manufactured to control processing of the wafer.

28. A strain gauge as claimed in claim 27, wherein said at least one electrical circuit controls processing of electro-deposition.